US009433957B2

(12) United States Patent
Nardi et al.

(10) **Patent No.: US 9,433,957 B2**
(45) **Date of Patent: Sep. 6, 2016**

(54) **COLD SPRAY SYSTEMS WITH IN-SITU POWDER MANUFACTURING**

(71) Applicant: **UNITED TECHNOLOGIES CORPORATION**, Farmington, CT (US)

(72) Inventors: **Aaron T. Nardi**, East Granby, CT (US); **Michael A. Klecka**, Vernon, CT (US); **Daniel V. Viens**, Mansfield Center, CT (US)

(73) Assignee: **UNITED TECHNOLOGIES CORPORATION**, Farmington, CT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/591,091**

(22) Filed: **Jan. 7, 2015**

(65) **Prior Publication Data**

US 2015/0190824 A1 Jul. 9, 2015

Related U.S. Application Data

(60) Provisional application No. 61/924,760, filed on Jan. 8, 2014.

(51) **Int. Cl.**

B05B 7/32 (2006.01)
B05B 7/14 (2006.01)
C23C 24/04 (2006.01)
B22F 9/14 (2006.01)

(52) **U.S. Cl.**

CPC ***B05B 7/1404*** (2013.01); ***B22F 9/14*** (2013.01); ***C23C 24/04*** (2013.01); *B22F 2999/00* (2013.01)

(58) **Field of Classification Search**

CPC B05B 3/026; B05B 9/03; B05B 11/0037; B05B 2203/0247

USPC 239/302, 310, 337, 349

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,713,491 A *	1/1973	Grabowski	A62C 37/00	169/28
4,452,239 A *	6/1984	Malem	A61M 15/00	128/200.14
7,878,258 B2 *	2/2011	Lindstrom	A62C 35/02	169/30
2003/0232132 A1 *	12/2003	Muehlberger	C23C 24/04	427/180
2005/0178851 A1 *	8/2005	Shutic	B05B 7/1454	239/124
2008/0271903 A1 *	11/2008	Lindstrom	A62C 35/02	169/61

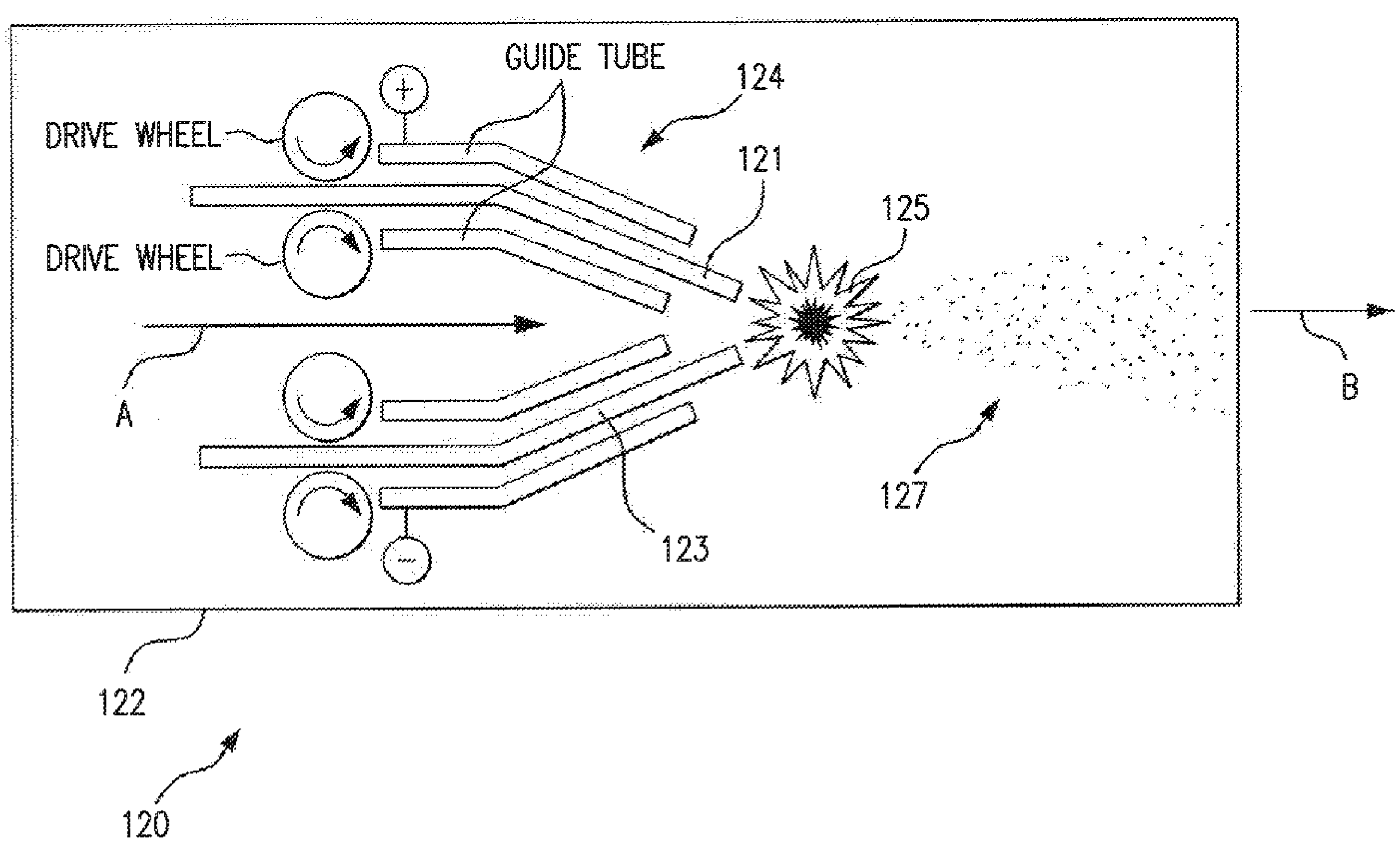
* cited by examiner

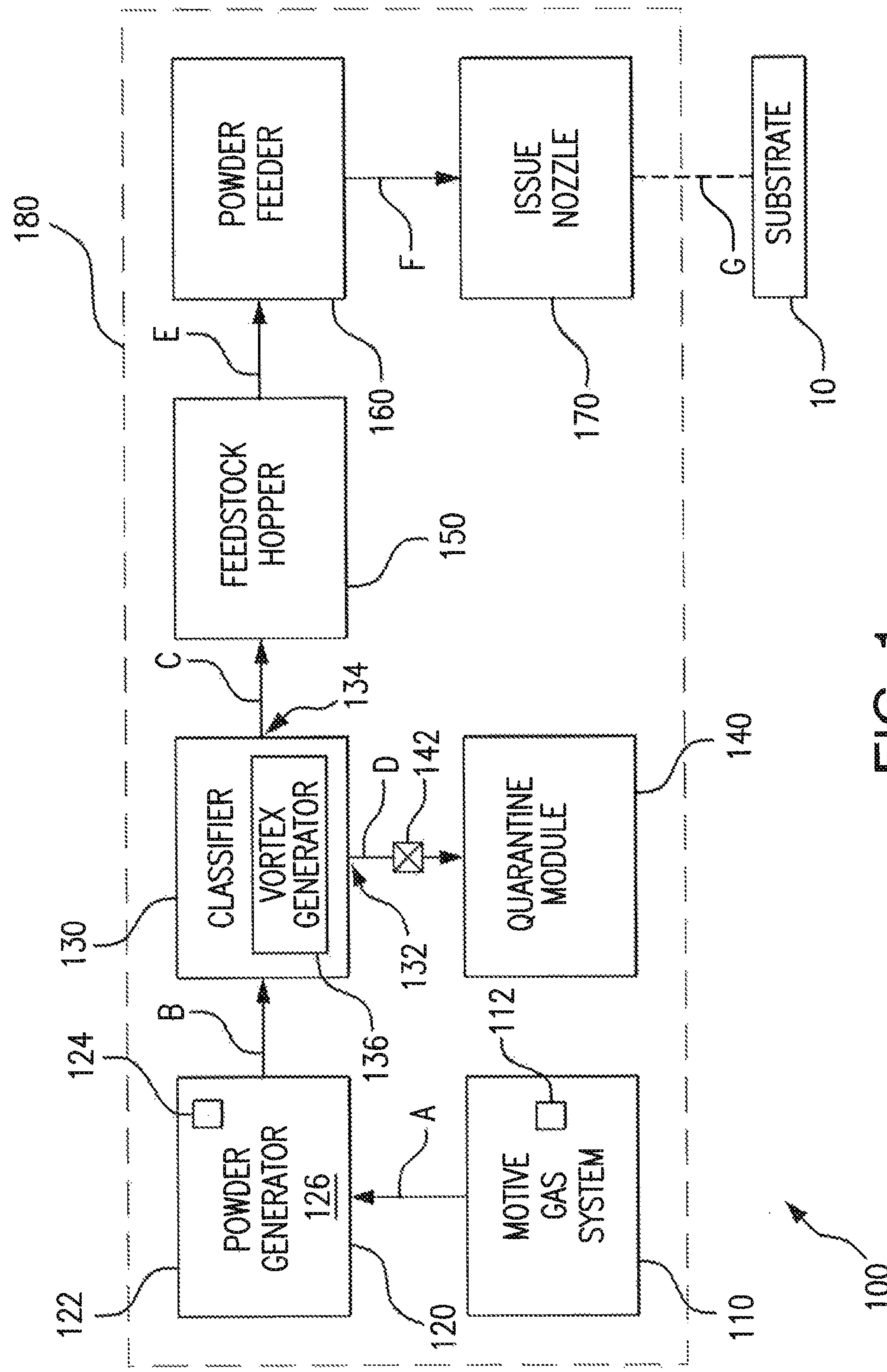
Primary Examiner — Davis Hwu
(74) *Attorney, Agent, or Firm* — Cantor Colburn LLP

(57) **ABSTRACT**

A cold spray system includes a powder generator and a powder feeder. The powder generator has a powder source disposed within a housing. The powder feeder is in fluid communication with the housing and the powder generator within the housing. A closed circuit defined from the powder generator to the powder feeder conveys powder from the powder generator to the powder feeder without exposing the powder to contaminates from outside the closed circuit.

19 Claims, 4 Drawing Sheets





POWDER GENERATOR 126
MOTIVE GAS SYSTEM
CLASSIFIER
VORTEX GENERATOR
QUARANTINE MODULE
FEEDSTOCK HOPPER
POWDER FEEDER
ISSUE NOZZLE
SUBSTRATE
A
B
C
D
E
F
G
10
100
110
112
120
122
124
130
132
134
136
140
142
150
160
170
180

FIG. 1

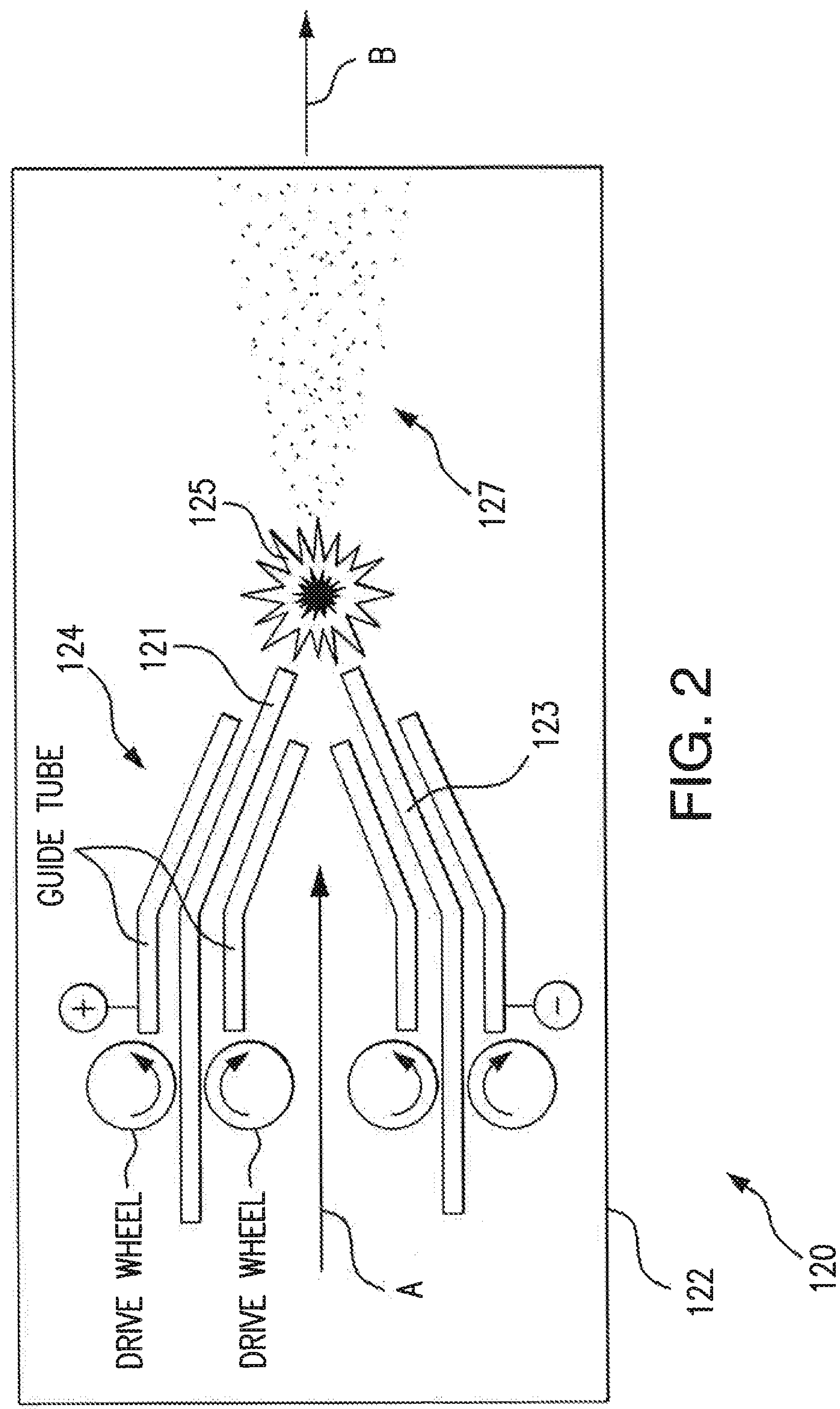

B
127
125
124
121
123
GUIDE TUBE
+
−
DRIVE WHEEL
DRIVE WHEEL
A
122
120

FIG. 2

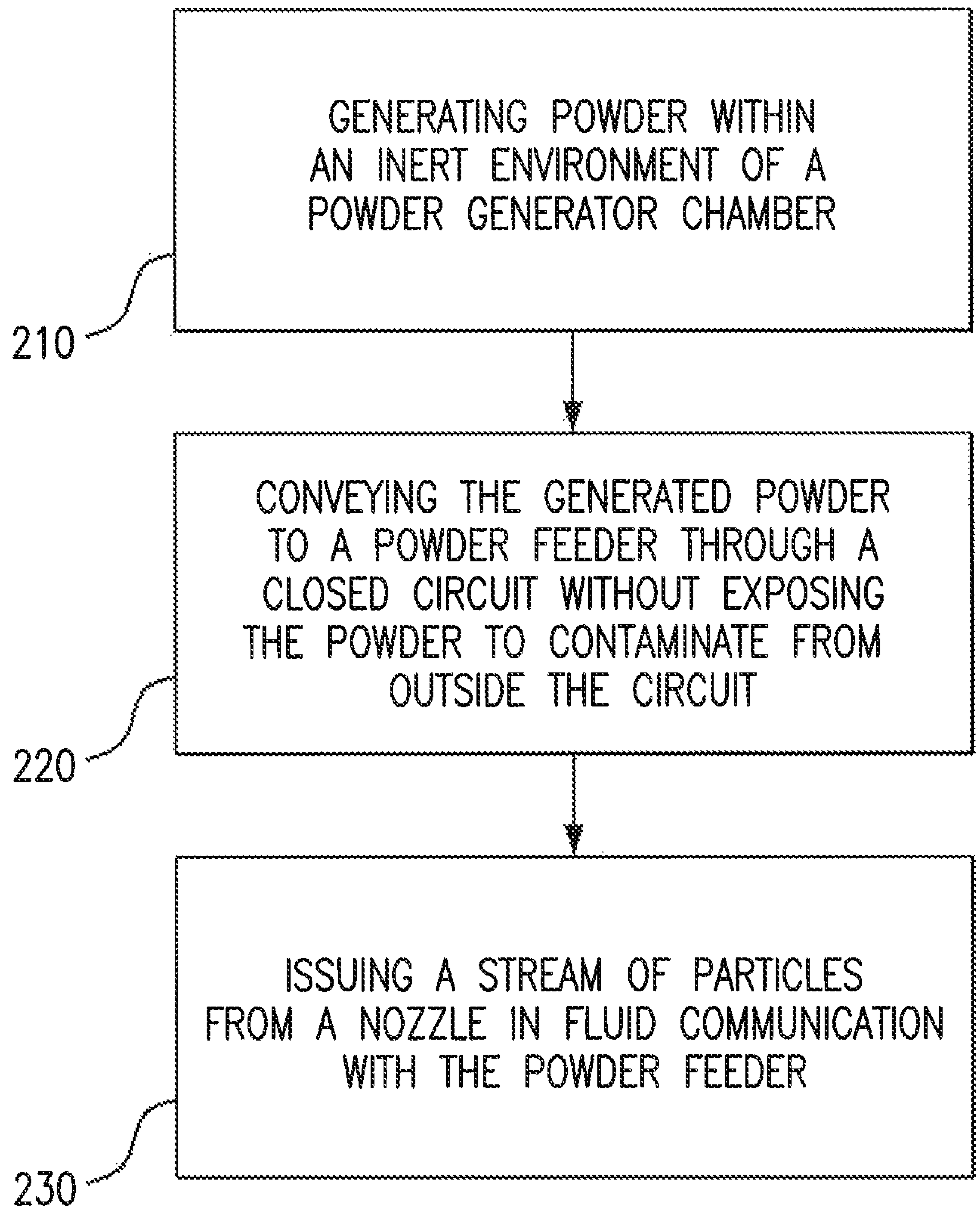
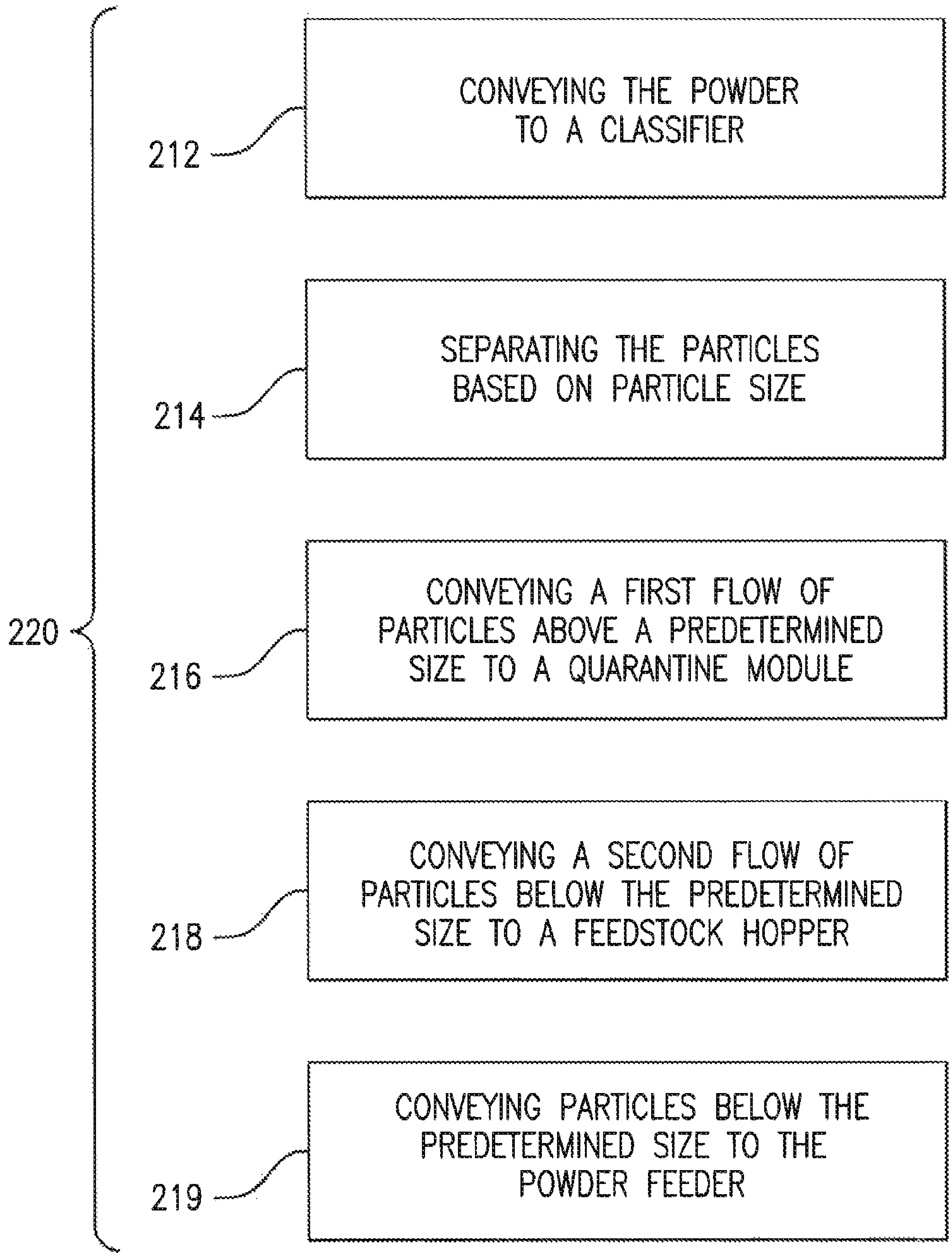

GENERATING POWDER WITHIN AN INERT ENVIRONMENT OF A POWDER GENERATOR CHAMBER
210
CONVEYING THE GENERATED POWDER TO A POWDER FEEDER THROUGH A CLOSED CIRCUIT WITHOUT EXPOSING THE POWDER TO CONTAMINATE FROM OUTSIDE THE CIRCUIT
220
ISSUING A STREAM OF PARTICLES FROM A NOZZLE IN FLUID COMMUNICATION WITH THE POWDER FEEDER
230

FIG. 3

200



CONVEYING THE POWDER TO A CLASSIFIER
212
SEPARATING THE PARTICLES BASED ON PARTICLE SIZE
214
CONVEYING A FIRST FLOW OF PARTICLES ABOVE A PREDETERMINED SIZE TO A QUARANTINE MODULE
216
220
CONVEYING A SECOND FLOW OF PARTICLES BELOW THE PREDETERMINED SIZE TO A FEEDSTOCK HOPPER
218
CONVEYING PARTICLES BELOW THE PREDETERMINED SIZE TO THE POWDER FEEDER
219

FIG. 4

COLD SPRAY SYSTEMS WITH IN-SITU POWDER MANUFACTURING

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of priority under 35 U.S.C. §119(e) to U.S. Provisional Application No. 61/924,760, filed Jan. 8, 2014, which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present disclosure relates to cold spray systems, and more particularly to powder feedstock manufacturing for cold spray systems.

2. Description of Related Art

Cold spray processes are used to develop coatings on target substrates. The coatings can be thin or thick, and form protective or performance enhancing layers on the substrate. The layers can also repair damage to the underlying substrate. The coatings can be formed from materials such as aluminum, copper, iron, or nickel. The coatings can also be formed from high strength alloys, such as Inconel® for example.

Cold spray processes form coatings by propelling powder feedstock particles to extremely high speeds by a carrier gas through a nozzle oriented toward a target substrate. The particles impact the substrate with sufficient kinetic energy to deform plastically and bond with the substrate, thereby forming a coating on the substrate. Cold spray is distinguishable from other spray deposition processes that melt the feedstock particles prior to propelling the particles toward the substrate, such as thermal and plasma spray processes. In contrast, cold spray processes typically do not change the physical state or chemical composition of the feedstock particles between their introduction into the system and their application to the substrate.

Not changing the state or chemistry of the feedstock particles has advantages and disadvantages. Since the chemical composition of the feedstock particles generally does not change introduction of the powder feedstock into the cold spray system and application to the substrate, coatings developed by cold spray processes generally have the same composition the powder feedstock material introduced to the cold spray system. For this same reasons, however, impurities or contaminates in powder feedstock introduced to the cold spray system can be incorporated into the coating developed on the substrate. This can pose challenges to cold spray processes using powder feedstock materials tending to form oxides or hydroxides when exposed to the ambient environment, like aluminum for example, as the oxides and hydroxides can change the coating composition, potentially altering the coating performance.

Conventional cold spray systems and methods have generally been considered satisfactory for their intended purpose. However, there is a need in the art for improved systems and methods for generating powder feedstock for cold spray systems. The present disclosure provides a solution for these problems.

SUMMARY OF THE INVENTION

A cold spray system includes a powder generator and a powder feeder. The powder generator incudes a powder source disposed within a housing. The powder feeder is in fluid communication with the powder generator. A closed circuit defined between the powder generator and powder feeder allows for conveying powder from the powder generator to the powder feeder without exposing the powder to contaminate (atmosphere, moisture, oxygen, etc.) from outside of the closed circuit.

In certain embodiments, the powder generator is maintained within an inert atmosphere. The powder generator can include feedstock wires housed within the powder generator. A feedstock wire can be electrically connected to voltage source terminal for developing an electric arc between the wire and a voltage return terminal. The arc can convert the wire into particulate, i.e. feedstock powder, as the wire is fed into the arc.

In accordance with certain embodiments, the system includes a motive gas system in fluid communication with the powder generator for propelling the feedstock powder through the closed circuit. The motive gas system can include a supply of inert gas such as argon, helium, and nitrogen. The feedstock powder particles manufactured by the powder generator and conveyed through the closed circuit to the powder feeder can have surface and interior portions with the same composition.

It is contemplated that the system can include a feedstock powder classifier in fluid communication with the powder generator. The classifier can remove feedstock powder of a size outside of a predetermined size range from a flow of feedstock powder conveyed through the closed circuit. The classifier can include a vortex generator for separating particles by particle size. The system can also include a quarantine module with an inert atmosphere and in selective fluid communication with the classifier. It is contemplated that the quarantine module can capture and impound particles separated by the classifier from the feedstock powder flow that are outside of the predetermined size range in an inert atmosphere. The classifier can have a first outlet in fluid communication with the feedstock hopper for discharging a flow of particles within the predetermined range and a second outlet in fluid communication with the quarantine module for discharging a flow of particles outside of the predetermined range. It is also contemplated that the closed circuit defined from the powder generator to the powder feeder can include both the classifier and feedstock hopper described above for conveying powder from the powder generator to the powder feeder without exposing the powder to contaminate from outside the closed circuit.

It is further contemplated that the system can include a feedstock hopper in fluid communication with the powder generator. The powder feeder can regulate between mismatches in powder generator feedstock powder manufacture rates and feedstock powder application rate. The system can include a nozzle in fluid communication with the powder generator for issuing a spray of powder at a substrate arranged opposite the nozzle.

A method of cold spraying includes generating powder, conveying the powder, and issuing the power as a spray. The generating operation includes generating powder within an inert environment of a powder generator chamber, the conveying operation includes conveying the generated powder to a powder feeder in fluid communication with the power generator through a closed circuit without exposing the powder to contaminate from outside the closed circuit, and the issuing operation includes issuing a stream of particles from a nozzle in fluid communication with the powder feeder.

These and other features of the systems and methods of the subject disclosure will become more readily apparent to those skilled in the art from the following detailed description of the preferred embodiments taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

So that those skilled in the art to which the subject disclosure appertains will readily understand how to make and use the devices and methods of the subject disclosure without undue experimentation, preferred embodiments thereof will be described in detail herein below with reference to certain figures, wherein:

FIG. **1** is a schematic view of an exemplary embodiment of a cold spray system with in-situ powder manufacturing constructed in accordance with the present disclosure, showing the elements of the closed circuit for preventing feedstock powder contamination;

FIG. **2** is a schematic cross-sectional view of the powder generator of the cold spray system of FIG. **1**, showing the powder generator;

FIG. **3** is a process flow diagram of an exemplary embodiment of a cold spray method, showing method operations; and

FIG. **4** is a process flow diagram of second cold spray method, showing conveying operations of the method.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Reference will now be made to the drawings wherein like reference numerals identify similar structural features or aspects of the subject disclosure. For purposes of explanation and illustration, and not limitation, a partial view of an exemplary embodiment of a cold spray system in accordance with the disclosure is shown in FIG. **1** and is designated generally by reference character **100**. Other embodiments of the cold spray system in accordance with the disclosure, or aspects thereof, are provided in FIGS. **2**-**4**, as will be described. The systems and methods described herein can be used for coating substrates with uniform material deposits, such as aluminum and aluminum alloys, for example.

Cold spray system **100** includes a motive gas system **110**, a powder generator **120**, a classifier **130**, and a quarantine module **140**. Cold spray system **100** also includes a feedstock hopper **150**, a powder feeder **160**, and an issue nozzle **170**. Motive gas system **110** is in fluid communication with powder generator **120**. Powder generator **120** is in fluid communication with classifier **130**. Classifier **130** is in fluid communication with feedstock hopper **150**. Classifier **130** is also in selective fluid communication with quarantine module **140**. Feedstock hopper **150** is in fluid communication with powder feeder **160**. Powder feeder **160** is in fluid communication with issue nozzle **170**.

Cold spray system **100** can be a closed system including a closed circuit **180** (indicated with the dashed lines in FIG. **1**). Closed circuit **180** can include powder generator **120** and powder feeder **160** for providing a flow of particles without contact with the atmosphere external to closed circuit **180** to prevent contact with the contaminants. Closed circuit **180** can also include at least one of motive gas system **110**, classifier **130**, quarantine module **140**, feedstock hopper **150**, and issue nozzle **170**. Closed circuit **180** can include suitable intervening elements, e.g. conduits, for placing system elements in fluid communication with one another.

Motive gas system **110** has a gas supply **112**. Powder generator **120** receives a motive gas flow A from motive gas system **110** (and gas supply **112**) for propelling particles produced in powder generator **120** through closed circuit **180**. Gas supply **112** can be an inert gas. Non-limiting examples of the inert gas include noble gases such as argon or helium, and inert gases such as nitrogen. Use of an inert gas allows for conveying powder from powder generator **120** to powder feeder **160** without exposing the powder to contaminate from outside closed circuit **180** as closed circuit **180** conveys the powder in an inert environment. Conveying the powder using an inert gas prevents incorporation of impurities such as oxides or hydroxides as well as other contaminates on the surface of the powder particles as the particles move through cold spray system **100**. Preventing incorporation contamination or impurities in the powder allows for production and delivery of particles to a substrate **10** such that the surface and interior portions of the particles have substantially the same composition (e.g. same chemical composition).

Powder generator **120** includes a housing **122** and a powder source **124**. Housing **122** defines an internal chamber **126** enveloping powder source **124** within an inert atmosphere. The inert atmosphere may include the same gas as supplied by motive gas system **110**.

Classifier **130** includes a first outlet **132**, a second outlet **134**, and a vortex generator **136**. The flow of particles received by classifier **130** can be of mixed size, and more specifically, the received particles can include particles in a range outside of a size range suitable for the cold spray process. Classifier **130** is configured for removing particles outside of the predetermined size range from the particle flow into classifier **130** using vortex generator **136**.

Vortex generator **136** is in fluid communication with powder source **124** and receives a flow of powder particles B from powder source **124**. Vortex generator **136** is also in fluid communication with quarantine module **140** through first outlet **132** and with feedstock hopper **150** through second outlet **134**. Vortex generator **136** separates particles outside of the predetermined size range using cyclic separation. Once separated, vortex generator **136** conveys particles within the predetermined size range to feedstock hopper **150** through first outlet **132** and particles outside of the predetermined size range to quarantine module **140** through second outlet **134**. It is contemplated that classifier **130** can employ other separation mechanisms for separating particles outside of the predetermined size range, such as screens and/or filters for example, such as would be suitable for an intended cold spray process.

Quarantine module **140** receives a flow of particles D outside of the predetermined range from classifier **130** through second outlet **134**. Quarantine module **140** selectively receives the particle flow through operation of a valve **142** and is configured for impounding (e.g. capturing) and storing the particles within an inert atmosphere. The inert atmosphere maintained within quarantine module **140** may include the same gas as supplied by motive gas system **110**. This potentially reduces the cost of operation of cold spray system **100** as the impounded particles can be recycled for use in another operation, such as by being introduced through an inert coupling into powder feeder **160** for deposition using a different cold spray process or substrate.

Feedstock hopper **150** receives a flow of particles C within the predetermined range from classifier **130** through first outlet **132**. Feedstock hopper **150** stores a supply of powder within the predetermined size range for supply at a uniform rate to powder feeder **160**. This allows for regulating mismatches between powder feedstock production rates in powder generator **120** and powder feedstock usage rates by a given cold spray process. It can also allow for intermittent operation of powder generator **120** during powder application operation by developing a 'buffer' stock of powder in feedstock hopper **150**.

Powder feeder **160** receives a particle flow E from feedstock hopper **150**. The flow rate of particle flow E may exceed that required by the cold spray process in terms mass flow rate or volume. Powder feeder **160** receives particle flow E and outputs a particles flow F which may be greater or less than that of particle flow F, such as by metering the received particle flow through a metering body, matching particle F to that required for a given cold spray process. Reconciliation of the rate of powder generation with the rate of powder use (issue) balances powder generation and utilization of powder by decoupling the powder manufacturing and powder deposition processes, enhancing operational flexibility of the system. For example, in processes where powder generator **120** creates powder more rapidly than deposited by cold spray system **100**, powder feeder **160** can reduce powder supplied to issue nozzle **170**. In processes where powder generator **120** tends to run behind, powder feeder **160** can augment powder flow by adding powder 'banked' in feedstock hopper **150** to powder generated by powder generator **120**.

Powder feeder **160** provides a metered particle flow as a particle flow F to issue nozzle **170**. Issue nozzle **170**, oriented toward a target substrate **10**, receives flow F from powder feeder **160** and propels the particles as a flow G toward substrate **10**. Particles within flow G have sufficient velocity to impact substrate **10** with sufficient energy to plastically deform and metallurgically bond with substrate **10** and/or the coating developed thereon. Since motive gas source **100** coveys the powder feedstock particles of flow G in an inert atmosphere, coatings formed by flow G are substantially uniform and is free of contamination and impurities such as oxides or hydroxides.

While cold spray system **100** is described above and illustrated in FIG. **1** as a system with seven components, (i.e. motive gas system **110**, powder generator **120**, classifier **130**, quarantine module **140** feedstock hopper **150**, powder feeder **160**, and issue nozzle **170**), embodiments of the system can employ a subset of the above described elements. For example, simplified embodiments of cold spray system **100** can be limited to motive gas system **110**, powder generator **120** and issue nozzle **170**. This potentially provides a cold spray system with enhanced operational flexibility, such as for a mobile cold spray operation for example.

With reference to FIG. **2**, powder generator **120** is shown schematically. Powder generator **120** includes powder source **124** enveloped within housing **122**. Powder source **124** includes a first feedstock wire **121** and a second feedstock wire **123**. Drive wheels and opposed guide tubes direct first and second feedstock wires **121** and **123** toward one another. Motive flow A, introduced into housing **122** by motive gas source **110** between the guide tubes and between first and second feedstock wire **121** and **123**, provides as inert atmosphere within powder generator **120** and conveys feedstock powder from powder generator **120** as the feedstock powder forms. First and second feedstock wires **121** and **123** are constructed from a suitable material for generating a coating on substrate **10** (shown in FIG. **1**). Non-limiting examples of suitable feedstock wire include aluminum or aluminum alloy wire. Suitable feedstock can also be in the form of bar or rod-shaped stock.

First and second feedstock wires **121** and **123** electrically connect to a voltage source terminal **126** (i.e. a positive voltage terminal) and a voltage return terminal **128** (i.e. a negative voltage terminal). Source voltage terminal **126** and return voltage terminal **128** establish a potential difference between the wires that increases as the wires approach one another. The potential difference is of suitable magnitude such that an arc **125** develops between adjacent ends of the wire. Arc **125** decomposes the adjacent ends of first and second feedstock wires **121** and **123**, forming feedstock powder particulate **127**. The drive wheels feed first and second feedstock wires **121** and **123** through each guide tube such that feedstock wire is fed into arc **125** at the same rate that arc **125** decomposes first and second feedstock wires **121** and **123**, continuously manufacturing of powder feedstock particulate **127**. This process occurs in an inert atmosphere (environment) maintained within housing **122**.

Motive gas source **110** introduces motive flow A into feedstock generator **120** such that powder feedstock particulate **127** forms particle flow B. Particle flow B exits powder generator **120** and is received by classifier **130**. Classifier **130** receives particle flow B and separates particles as described above.

Embodiments of the systems and methods described herein are not limited to twin wire powder generators. For example, powder stream **127** can be manufactured using a single wire arc source. Powder stream **127** can also be manufactured using alternate electrode geometries employed within the inert atmosphere chamber. Embodiments of cold spray system **100** can also include powder generators with dynamic seals configured to receive wire fed from one or more wire spools arranged externally to housing. This potentially makes operation more reliable by allowing for extending operation without disturbing the inert atmosphere within the system.

With reference to FIG. **3**, a cold spray method **200** is shown. Cold spray method **200** includes (a) generating a powder within an inert environment of a powder generator chamber at a step **210**, (b) conveying the generated powder to a powder feeder through a closed circuit without exposing the powder to contaminate from outside the closed circuit at a step **220**, and (c) issuing a flow of particles from a nozzle in fluid communication with the powder feeder at a step **230**.

With reference to FIG. **4**, conveying step **220** can additionally include (1) conveying powder to a classifier at a step **212**, (b) separating the particles based on particle size at step a **214**, (c) conveying a first flow of particles above a predetermined size to a quarantine module at a step **216**, (d) conveying a second flow of particles below the predetermined size to a feeder hopper at a step **218**, and (e) conveying particles below the predetermined size (e.g. the second flow) to the powder feeder at a step **219**. Optionally, the first flow can be introduced to the powder feeder via an inert coupling for subsequent application to a substrate.

In certain embodiments, the systems and methods described herein potentially provide very thick deposits of high quality and/or strength materials. Systems and methods described herein can also provide a process akin to conventional additive manufacturing processes. In certain embodiments, the systems and methods described herein allows for storing powder feedstock (subsequent to manufacture) in an inert atmosphere prior to deposition. This removes the constraint of simultaneous powder generation and deposition characteristic of conventional cold spray systems. It also potentially allows for shifting in time deposition of powder and production and classification of powder—without exposure of the powder to the atmosphere and/or contaminates during the intervening period.

The methods and systems of the present disclosure, as described above and shown in the drawings, can provide for coatings with superior properties including uniformity, and particularly, absence of oxides, hydroxides, and the like. While the apparatus and methods of the subject disclosure have been shown and described with reference to preferred embodiments, those skilled in the art will readily appreciate that changes and/or modifications may be made thereto without departing from the spirit and scope of the subject disclosure.

What is claimed is:

1. A cold spray system, comprising:

a powder generator having a powder source disposed within a housing;

a powder feeder in fluid communication with the housing, wherein a closed circuit with an inert atmosphere is defined from the powder generator to the powder feeder for conveying powder from the powder generator to the powder feeder without exposing the powder to contaminates from outside the closed circuit; and

a motive gas system in fluid communication with the powder generator for propelling particles produced in the powder generator through the closed circuit.

2. A system as recited in claim **1**, wherein in the powder generator is housed within a generator chamber with an inert atmosphere.

3. A system as recited in claim **1**, wherein the powder generator, powder feeder, and closed circuit are configured to supply particles having surface and interior portions with substantially the same composition.

4. A system as recited in claim **1**, further comprising voltage source and return terminals operatively associated with the powder generator for developing an arc within the generator.

5. A system as recited in claim **4**, further comprising first and second feedstock wires, bars, or rods connected to the voltage source and return terminals for generating an arc between the wires.

6. A system as recited in claim **5**, wherein the first and second feedstock wires include aluminum or aluminum alloy.

7. A system as recited in claim **6**, further comprising respective first and second wire feeders configured to feed the first and second wires within the chamber as the first and second wires are consumed to produce particles.

8. A system as recited in claim **1**, wherein the motive gas system includes a supply of inert gas selected from the group consisting of argon, helium, and nitrogen.

9. A cold spray system, comprising:

a powder generator having a powder source disposed within a housing;

a powder feeder in fluid communication with the housing, wherein a closed circuit with an inert atmosphere is defined from the powder generator to the powder feeder for conveying powder from the powder generator to the powder feeder without exposing the powder to contaminates from outside the closed circuit and

a classifier in fluid communication with the powder generator, wherein the classifier is configured for removing particles outside of a predetermined size range from a particle flow through the closed circuit.

10. A system as recited in claim **9**, wherein the classifier includes a vortex generator for separating particles by particle size.

11. A system as recited in claim **10**, further including a quarantine module with an inert atmosphere in selective fluid communication with the classifier for capturing particles above a predetermined size separated by the classifier.

12. A system as recited in claim **11**, wherein the quarantine module has an inert atmosphere for storing particles above a predetermined size separated by the classifier.

13. A cold spray system, comprising:

a powder generator having a powder source disposed within a housing;

a powder feeder in fluid communication with the housing, wherein a closed circuit with an inert atmosphere is defined from the powder generator to the powder feeder for conveying powder from the powder generator to the powder feeder without exposing the powder to contaminates from outside the closed circuit; and

a feedstock hopper in fluid communication with the powder generator and with the powder feeder for storing particles to regulate between a particle production rate of the powder generator and a particle usage rate of the powder feeder.

14. A system as recited in claim **1**, further including an issue nozzle in fluid communication with the powder generator and configured for issuing a spray of powder at a substrate arranged opposite the nozzle.

15. A cold spray system, comprising:

a powder generator having a powder source disposed within a housing;

a classifier for removing particles outside of a predetermined size range from a particle flow received from powder generator;

a feedstock hopper for storing particles received from the classifier to regulate between a particle production rate of the powder generator and a particle usage rate of the powder feeder; and

a powder feeder for feeding a consistent flow of particles received from the feedstock hopper, wherein a closed circuit with an inert atmosphere is defined from the powder generator to the powder feeder including the classifier and feedstock hopper for conveying powder from the powder generator to the powder feeder without exposing the powder to contaminates from outside the closed circuit.

16. A system as recited in claim **15**, further including a quarantine module with an inert atmosphere in selective fluid communication with the classifier for capturing particles above a predetermined size separated by and received from the classifier.

17. A system as recited in claim **16**, wherein the quarantine module has an inert atmosphere for storing particles above a predetermined size separated by the classifier.

18. A system as recited in claim **16**, wherein the classifier has a first outlet in fluid communication with the feedstock hopper for discharging a flow of particles within the predetermined range, wherein the classifier has a second outlet in fluid communication with the quarantine module for discharging a flow of particles outside of the predetermined range.

19. A method of cold spraying, comprising:

generating powder within an inert environment of a powder generator chamber;

removing particles of a predetermined size from the generated powder;

conveying the generated powder having particles smaller than the predetermined size to a powder feeder in fluid communication with the power generator through a closed circuit without exposing the powder to contaminate from outside the closed circuit; and

issuing a flow of particles as a spray from a nozzle in fluid communication with the powder feeder.

* * * * *